INPUT INTERACTIONS IN FLORIDA ORANGE PRODUCTION

By

CHEN-TUAN LI

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CHAPTER I

INTRODUCTION

Economic Importance of Orange Industry

In the 1925-26 season, 163,100 acres were devoted to the culture of all citrus crops in Florida. Of these, approximately 67 per cent were commercial oranges and the remainder (about 53,900 acres) were grapefruit, tangerines, lemons, limes, etc. In the same season, the orange crop was valued at $22.7 million[1] and comprised 56.5 per cent of the value of all Florida citrus for that year.

The farm value of citrus sold in the 1940-41 season was $32.4 million, of which $22.4 million[2] came from sales of commercial oranges. Oranges accounted for 69.1 per cent of all citrus sold in the state during that season.

The total farm value of sales of commercial oranges in Florida in the 1950-51 season had increased to $109.9 million;[3] this represented 74.3 per cent of all citrus sold. In the 1959-60 season the gross value of sales of commercial oranges was $177.9 million[4] or 80.9 per cent of all citrus sold.

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[1]Florida Crop and Livestock Reporting Service, Florida Citrus Fruit Annual Summary 1960 (Orlando, Florida: 1960).

[2]*Ibid.*

[3]*Ibid.*

[4]*Ibid.*

The sales value of commercial oranges in Florida has increased very rapidly each year. For instance, total Florida farm income in 1953 was $562 million of which 29 per cent[5] come from commercial oranges sold; in 1956 the figure was 30.5 per cent. In 1957 and 1959 the sales value of the commercial orange crop represented 27.4 per cent and 34.1 per cent, respectively, of the cash receipts from marketings of all Florida farm products.

Contribution to national production

Oranges are produced commercially in four states. These are Florida, California, Texas and Arizona.

Florida's relative position in national orange production has risen considerably in the past 25 years. The 1959-60 proportion is approximately 2.5 times the percentage for 1925-26. Florida's relative share of national acreage during the same period has increased to 1.8 times the proportion for 1925-26 (Table 1).

In the 1959-60 season the total production of commercial oranges in the United States was 126.8 million boxes of which 91.5 million boxes or 72.2 per cent were produced in Florida. This crop was produced on 581,900 acres of land; 70 per cent of this acreage was in Florida.

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[5]Elmo F. Scarborough (ed.), Annual Agricultural Statistical Summary 1959-60 Season (Jacksonville: Florida State Marketing Bureau, 1960).

TABLE 1.--Florida orange production and acreage relative to United States production and acreage, selected seasons, 1925-60

Season	Proportion of National Production	Proportion of National Acreage
	Per cent	Per cent
1925-26	28	37
1930-31	32	40
1935-36	32	44
1940-41	35	46
1945-46	50	49
1950-51	58	55
1955-56	69	64
1956-57	71	69
1957-58	76	67
1958-59	66	68
1959-60	72	70

Source: Compiled from Florida Crop and Livestock Reporting Service, Florida Citrus Fruit Annual Summary 1960.

The farm value of all sales of commercial oranges in Florida amounted to $177.9 million in 1959-60. This was 64 per cent of the sales value of all commercial oranges in the United States.[6]

Trends in Florida orange production

Information about the tendency of trends in this industry is essential to an evaluation of its status. A study of these trends in orange production in the past decade will be very helpful for estimating or predicting future orange production.

The trend in bearing trees is a major determinant of the trend in orange production. Data showing tendencies in numbers of bearing commercial orange trees are shown in Table 2.

[6]Florida Crop and Livestock Reporting Service.

TABLE 2.--Number of bearing commercial orange trees in Florida, 1951-60 seasons

Season	Bearing Trees	Increase (+) or Decrease (-)
	Thousands	Per cent
1951-52	20,937	. .
1952-53	21,567	+ 3.00
1953-54	22,074	+ 2.35
1954-55	23,166	+ 4.95
1955-56	24,850	+ 7.26
1956-57	24,274	- 2.32
1957-58	24,860	+ 2.41
1958-59	24,951	+ 0.37
1959-60	25,062	+ 0.44

Source: Compiled from Florida State Marketing Bureau, Annual Agricultural Statistical Summary, 1951-60 Seasons.

Since the 1951-52 season to the present there have been increases, except in those years following frost or other severe injuries, in orange production each year. Data in Table 3 illustrate these tendencies.

TABLE 3.--Total orange production in Florida, 1951-52 to 1959-60 seasons

Season	1,000 Boxes
1951-52	78,600
1952-53	72,200
1953-54	91,300
1954-55	88,400
1955-56	91,000
1956-57	93,000
1957-58	82,500
1958-59	86,000
1959-60	91,500

Source: Compiled from Florida Crop and Livestock Reporting Service, Florida Citrus Fruit Annual Summary 1960.

Purpose and Scope of Study

Purpose of study

The major purpose of this study is to analyze the data which can provide a basis for evaluating the importance of tree characteristics, disease and location on potential orange production in Florida. Specifically, the main objectives are as follows:

1. To develop a theoretical production model showing interrelations of various input variables.
2. To determine factor interrelations in Florida orange production and to test their significance. Included are the following:
    a. Relations between rootstocks, varieties and age groups.
    b. Relations between rootstocks, varieties and locations.
    c. Relations between varieties, age groups and locations.
    d. Relations between varieties, age groups and diseases.
    e. Relations between age groups, locations and diseases.
    f. Relations between age groups, locations and rootstocks.
    g. Relations between locations, diseases and rootstocks.
    h. Relations between locations, diseases and varieties.
    i. Relations between diseases, rootstocks and varieties.
    j. Relations between diseases, rootstocks and age groups.
3. To evaluate the possible economic effect on the Florida orange industry of outbreaks of various diseases.

Scope of study

This study is largely concerned with tree characteristics, disease and location relationships which affect the volume of orange production.

Five chapters are included in this dissertation. Chapter I provides information on the importance of the orange industry and

trends in production and on the objectives and procedures used in the study. Chapter II gives a theoretical consideration of the relationship of tree characteristics, diseases and locations to orange production.

The determination of interrelations between variables and tests of their significance are covered in Chapter III. An interpretation of the economic effect of diseases and other factors on orange production is the subject of Chapter IV. A summary and conclusion appear in the last chapter.

Method of Procedure

Many factors are related to orange production. Such factors include variety, rootstock, tree age, planting system, disease, cultural practices, location, etc. Those variables can also be subdivided into many further classifications. Because time and resources imposed many limitations, it became necessary to delimit the scope of the study to the factors considered most important.

It was indicated previously that this study is largely concerned with tree characteristics, diseases and locations. Speaking more specifically, the data treated include variety, rootstock, tree age, disease and location.

Of the hundreds of orange varieties, only a small number are grown commercially in Florida. Commercial oranges are generally classified as early, mid-season and late.

Orange varieties are roughly classified as: Hamlin, early seedy, Navel and other unidentified early oranges; Jaffa, mid-season

seedy, seedling and other unidentified mid-season oranges. Late oranges include only Valencia and other unidentified late.

Rootstocks include nine types. These are sour orange, rough lemon, trifoliate, Cleopatra, sweet orange, hybrids, own root, other unidentified and mixed.

A division into six tree age groups was made. These include non-bearing resets and age groups of 1 to 4, 5 to 9, 10 to 14, 15 to 24 and 25 years or more.

Diseases in orange groves can be classified as nine kinds: psorosis, tristeza, spreading decline, water damage, blight, xyloporosis, foot rot, heart rot and lightning injury.

Five regions are included in this study (Figure 1). They are:

1. North Fringe: Alachua, Duval, Citrus, Flagler, Hernando, Marion, Putnam, St. Johns, Sumter and Volusia counties.
2. West Coast: Charlotte, Collier, Hillsborough, Lee, Manatee, Pasco, Pinellas and Sarasota counties.
3. Upper Interior: Lake, Orange and Seminole counties.
4. Lower Interior: Hardee, Hendry, Highlands, DeSoto, Okeechobee, Osceola and Polk counties.
5. East Coast: Brevard, Broward, Dade, Indian River, Martin, Palm Beach and St. Lucie counties.

The factors to be considered in this study are those listed above. Unidentified or unspecified factors such as unidentified

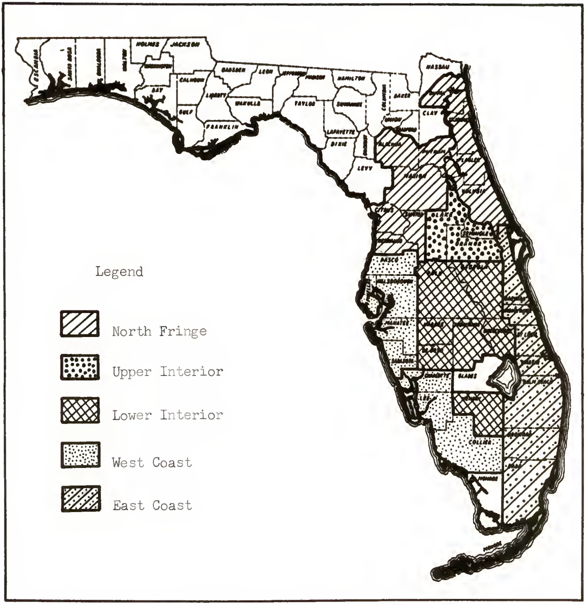

Figure 1.--Florida citrus regions

rootstock or variety will be excluded. Only the specified factors with distinguishable characteristics will be treated in this study.

The classifications of most factors studied are based upon their natural characteristics. However, some are classified rather roughly and arbitrarily because no clearly defined natural boundaries exist. Therefore, subjective divisions were often unavoidable. The division in various locations is a notable example.

Source of data

The data used in this study are all secondary data. The major source of the data used in this study is the Florida Citrus Census. This census, begun in the fall of 1954 and completed in the fall of 1957, was done by the State Plant Board[7] in cooperation with the Agricultural Marketing Service of the United States Department of Agriculture, the Florida Citrus Commission and Florida Citrus Mutual.

The information for each orange grove designated on the citrus census included major factors influencing production such as rootstock, tree age, tree spacing, vacancies, non-bearing resets, tree count by variety and condition of grove with respect to disease. This information was obtained in a tree-by-tree inspection made by citrus census crews riding in jeeps. Every crew made a report every day to the State Plant Board and the Florida Citrus Commission. All of the information obtained in the field was coded and punched on IBM cards. Data on these cards provided information for researchers as well as for the citrus industry.

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[7]Now the Department of Agriculture Division of Plant Industry of the Florida State Department of Agriculture.

Other sources of data are Florida Citrus Annual Summary, published every year by the Florida Crop and Livestock Reporting Service in Orlando, Florida, and Annual Agricultural Statistical Summary, published by the Florida State Marketing Bureau in Jacksonville.

About 119,000 IBM cards were sorted three times to provide the information necessary for this study. In addition to these data, information obtained in more recent citrus tree surveys was used in projecting orange yields over future periods.

Analysis of data

It has been indicated that only five factors--variety, rootstock, tree age, location and disease--will be considered in this study. These five factors will be combined into ten sets or groups. They are: (1) variety by age group on rootstock, (2) variety by location on rootstock, (3) age group by location of variety, (4) age group by disease of variety, (5) location by disease of tree age group, (6) location by rootstock of age group, (7) disease by rootstock in location, (8) disease by variety in location, (9) rootstock by variety with disease, and (10) rootstock by age group with disease.

A total of 82 tables, each one including three factors, were constructed with empirical data obtained from IBM cards.[8] All those data are considered as sampling over a period of time. Therefore the simple chi-square technique was employed to test the relations among the three factors studied for each test made.

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[8]Only the most important of these tables are shown in this report.

CHAPTER II

SOME THEORETICAL CONSIDERATIONS RELATIVE TO ORANGE PRODUCTION

General Production Models

Economic activity of human beings in daily life may be classified in two phases: production and consumption. Production may be defined as all of the processes involved in combining and coordinating materials and forces in the creation of valuable goods or services. The former (materials and forces) are termed "inputs" and the latter (goods or services) are called "outputs." However, the terms input and output relate only to a particular productive activity. A good or service which is an "output" in one productive activity may be an "input" in another.

Input factors can be classified as two kinds: those that vary and those that do not vary with the amount of product. The former are referred to as variable factors and the latter as fixed factors. Raw materials and labor, for example, are variable factors while plants or certain machines in them are fixed factors. Variable factors also can be classified as two kinds: those which flow without a break from one individual to the next are called continuous variable factors and those with an enumeration of successions are called discrete variable factors.

The problem of production is to study the relationship between input and output under the assumption that the fixed factor remains constant; i.e., there is a given plant, a factory, a piece of land, etc. This input and output relationship, or production function, is expressed as $\phi = f\ (x_1,\ x_2,/x_3,\ldots x_n)$, where ϕ refers to a single output, x_1 and x_2 refer to variable factors and $x_3 \ldots x_n$ are fixed factors. The function can be fitted to any production problem. For instance, suppose we let labor and fertilizer be variable factors and an orange tree the fixed factor; then the orange tree production function in a particular year can be shown as $\phi = f\ (l,f,t)$ where ϕ, l, f and t refer to output, labor, fertilizer and tree, respectively. However, if we only consider the orange production problem over a number of years for a particular tree, then the production function can be expressed as $\phi = f\ (t/tr.)$, where ϕ is orange output, t refers to a number of years--a variable factor--and tr. refers to a particular tree. This relationship or production function is useful here for theoretical discussion only, but practical solutions may be obtained if actual data were available and analyzed.

Most production economists are interested in quantitative relationships of inputs and outputs. Several functions for estimating quantitative input-output data have been developed. One of these is:

$$\phi = M - AR^x \tag{1}$$

where ϕ is total production, x is the total input, M is the maximum output which can be obtained by use of the variable input, R is the

ratio by which increments are added to total production, and A is the total increase in total output which can be obtained by increasing x.

This function was suggested by Spillman and is known as the Spillman function. The assumption made for this function is that there is a constant ratio of one marginal product to the succeeding marginal product,[1] that is:

$$R = \frac{d_2\phi}{d_1\phi} = \frac{d_3\phi}{d_2\phi} = \frac{d_4\phi}{d_3\phi} = \ldots = \frac{d_n\phi}{d_{n-1}\phi} \qquad (2)$$

This assumption may hold true for some situations. However, it need not hold true in all, or even in the majority of, cases.[2]

Another is the power or Cobb-Douglas[3] function which is usually expressed as:

$$\phi = AX^b \qquad (3)$$

where ϕ refers to output and X refers to input variable. A is a constant and b is the elasticity of production; b represents the percentage change in output associated with each 1 per cent increase in a given input when other inputs are held constant. This function is estimated in the form of

$$\log \phi = \log A + b \log X \qquad (4)$$

Parameters can be estimated from the logarithmic function by the technique of least squares. This function allows increasing, constant, or decreasing marginal productivity, but only one of these

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[1] Earl O. Heady, Economics of Agricultural Production and Resource Use (New York: Prentice Hall, 1952), p. 58.

[2] Earl O. Heady et al., Resource Productivity, Returns to Scale and Farm Size (Ames: Iowa State College Press, 1956), p. 9.

[3] Ibid., p. 8.

and not a combination. It can be seen from the first derivative of equation (3), that is:

$$\frac{d\phi}{dx} = bAX^{b-1} = \frac{bAX^b}{X} \qquad (5)$$

Then if b - 1, the marginal productivity $(\frac{d\phi}{dx})$ will be constant, or equal to A. If b>1, then the marginal productivity $(\frac{d\phi}{dx})$ will decline as X increases. Otherwise, if b<1, then the marginal productivity $(\frac{d\phi}{dx})$ will increase as the input factor X increases. This function assumes that the elasticity of production is constant over the entire range of input factors; that is, each percentage increase in input adds the same percentage increase in outputs. The constant elasticity of production can be shown as:

$$E_p = \frac{d\phi_1}{dX_1} \cdot \frac{X_1}{\phi_1} = \frac{d\phi_2}{dX_2} \cdot \frac{X_2}{\phi_2} = \ldots = \frac{d\phi_n}{dX_n} \cdot \frac{X_n}{\phi_n} \qquad (6)$$

The elasticity of production is constant, because $\frac{d\phi}{dX} = \frac{bAX^b}{X}$ and $\phi = AX^b$. If $\frac{bAX^b}{X}$ and AX^b are substituted in equation (6), then:

$$E_p = \frac{b_1A_1X_1{}^{b_1}}{X} \cdot \frac{X_1}{A_1X_1{}^{b_1}} = \frac{b_2A_2X_2{}^{b_2}}{X_2} \cdot \frac{X_2}{A_2X_2{}^{b_2}} = \ldots = \frac{b_nA_nX_n{}^{b_n}}{X_n} \cdot \frac{X_n}{A_nX_n{}^{b_n}}$$

or $E_p = b_1 = b_2 = \ldots - b_n$; therefore the elasticity of production is constant at the level of $b_1 = b_2 = \ldots = b_n$. This assumption also need not hold true in all cases.[4]

The Spillman and Cobb-Douglas functions are useful for continuous data only. If we study the relationship of fertilizer or labor inputs to orange production, these functions would be highly recommended as appropriate techniques.

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[4]*Ibid.*, p. 9.

This study deals with discrete variables of orange production. It is thus insufficient to employ either the Spillman or Cobb-Douglas production functions as tools. A special orange production model deserves consideration.

Production Model of Total Orange Production in Florida

Total orange production in a given period of time or a particular season may be estimated in the simplest form as:

$$Q = N\bar{\Phi} \tag{7}$$

where Q = total boxes of oranges produced

N = Number of bearing orange trees in the particular season

$\bar{\Phi}$ = average yield per tree in boxes

There is no difficulty in obtaining the number of bearing trees in a particular season. Several methods can be used. It may be gained by sampling methods or using citrus census data with appropriate adjustments.

The average yield per tree is equal to the summation of the yield of each individual tree, divided by the number of bearing trees; this can be shown as

$$\bar{\Phi} = \frac{\sum_{i=1}^{n} \Phi}{N} \tag{8}$$

To substitute $\bar{\Phi}$ of equation (8) in equation (7), then the total yield of oranges will be

$$Q = \sum_{i=1}^{n} \Phi \tag{9}$$

Production Model of Individual Orange Trees

If we want to obtain a precise estimation of the total production of commercial oranges, it is necessary to consider the yield of individual trees. The yield of an individual tree is the function of many factors such as variety, rootstock, tree age, location, disease, cultural practice, etc., and the contribution of those factor interactions. The production model of individual orange trees can be shown as:

$$\begin{aligned}
\phi = {} & a_0 + a_1X_i + a_2X_j + a_3X_k + a_4X_1 + a_5X_m + a_6X_n + b_1X_iX_j \\
& + b_2X_iX_k + b_3X_iX_1 + b_4X_iX_m + b_5X_iX_n + b_6X_jX_k + b_7X_jX_1 \\
& + b_8X_jX_m + b_9X_jX_n + b_{10}X_kX_1 + b_{11}X_kX_m + b_{12}X_kX_n + b_{13}X_1X_m \\
& + b_{14}X_1X_n + b_{15}X_mX_n + c_1X_iX_jX_k + c_2X_iX_jX_1 + c_3X_iX_jX_m \\
& + c_4X_iX_jX_n + c_5X_iX_kX_1 + c_6X_iX_kX_m + c_7X_iX_kX_n + c_8X_iX_1X_m \\
& + c_9X_iX_1X_n + c_{10}X_iX_mX_n + c_{11}X_jX_kX_1 + c_{12}X_jX_kX_m + c_{13}X_jX_kX_n \\
& + c_{14}X_jX_1X_m + c_{15}X_jX_1X_n + c_{16}X_jX_mX_n + c_{17}X_kX_1X_m + c_{18}X_kX_1X_n \\
& + c_{19}X_kX_mX_n + c_{20}X_1X_mX_n \qquad (10)
\end{aligned}$$

where ϕ = yield of an individual tree,

b_i and c_j = coefficients of that cell,

$i = 1, 2, 3 \ldots\ldots\ldots\ldots 15$
$j = 1, 2, 3 \ldots\ldots\ldots\ldots 20$

X_i = varieties

i: 0 = Unidentified orange
1 = Hamlin
2 = Early Oranges
3 = Navel
4 = Unidentified early
5 = Jaffa

6 = Mid-season
7 = Seedling
8 = Unidentified mid-season
9 = Valencia
10 = Unidentified late

X_j = Age groups

j: 1 = Non-bearing resets
2 = Under 4 years
3 = 5-9 years
4 = 10-14 years
5 = 15-24 years
6 = 25 years and over

X_k = Diseases

k: 0 = Other disease
1 = Psorosis
2 = Tristeza
3 = Spreading decline
4 = Water damage
5 = Blight
6 = Xyloporosis
7 = Foot rot
8 = Heart rot
9 = Lightning injury

X_l = Rootstocks

l: 1 = Sour orange
2 = Rough lemon
3 = Trifoliate
4 = Cleopatra
5 = Sweet orange
6 = Hybrids
7 = Own root
8 = Others and unidentified
9 = Mixed

X_m = Locations

m: 1 = Northern fringe
2 = West coast
3 = Upper interior
4 = East coast
5 = Lower interior

X_n = Unidentified factors

n: Unidentified factors

The primary concern of this study is the identified factors. This is not because the unidentified factors are not important. Rather, it is because no proper method to evaluate their importance to orange production is available. This study is concerned only with the variety, rootstock, disease, tree age and location. In order to estimate the effect of those factors and the contribution of their interactions accurately, it is necessary to hold the unidentified factors constant or to ignore them. Therefore, this model can be simplified as:

$$\begin{aligned}\phi = {} & a_0 + a_1X_i + a_2X_j + a_3X_k + a_4X_l + a_5X_m + b_1X_iX_j + b_2X_iX_k \\ & + b_3X_iX_l + b_4X_iX_m + b_5X_jX_k + b_6X_jX_l + b_7X_jX_m + b_8X_kX_l \\ & + b_9X_kX_m + b_{10}X_lX_m + c_1X_iX_jX_k + c_2X_iX_jX_l + c\ X_3X_iX_{j\ m} + c_4X_iX_kX_l \\ & + c_5X_iX_kX_m + c_6X_iX_lX_m + c_7X_jX_kX_l + c_8X_jX_kX_m + c_9X_jX_lX_m \\ & + c_{10}X_kX_lX_m \qquad (11)\end{aligned}$$

For example: A 30-year rough lemon rootstock Hamlin orange tree in the East coast Region which has heart rot can be shown in its production model as:

$$\begin{aligned}\phi = {} & a_0 + a_1X_1 + a_2X_5 + a_3X_8 + a_4X_2 + a_5X_4 + b_1X_1X_5 + b_2X_1X_8 \\ & + b_3X_1X_2 + b_4X_1X_4 + b_5X_5X_8 + b_6X_5X_2 + b_7X_5X_4 + b_8X_8X_2 \\ & + b_9X_8X_4 + b_{10}X_2X_4 + c_1X_1X_5X_8 + c_2X_1X_5X_2 + c_3X_1X_5X_4 \\ & + c_4X_1X_8X_2 + c_5X_1X_8X_4 + c_6X_1X_2X_4 + c_7X_5X_8X_2 + c_8X_5X_8X_4 \\ & + c_9X_5X_2X_4 + c_{10}X_8X_2X_4 \qquad (12)\end{aligned}$$

Theoretical Consideration of Tree Count Model

The coefficients of this model can be estimated if empirical production data were available. Unfortunately, sufficient empirical data are not now at hand. Thus it would serve no purpose at this point to estimate the coefficients and construct a production model. Instead, emphasis will be placed in determining whether or not there is some interaction among those variable factors of this model. In other words, one of the purposes of this study is to determine whether these coefficients are zero or not zero. That is:

$a_i \gtrless 0$; $b_i \gtrless 0$; $c_i \gtrless 0$

There is no doubt that each individual factor has an effect on orange production; that is, the coefficients of the first order, a_i, may be either larger or smaller than zero, but not zero. However, we need only to determine the coefficients of the second order, b_i, and the third order, c_i. If a third order coefficient were not zero, then the corresponding factor's coefficient of the second order would also not be zero. If the third order coefficient were zero, then the second order coefficients need also to be tested.

If the coefficient of a cell were zero, it means there is no interaction effect on yield of those factors. If it were not zero, then we say that there is some interaction effect on the yield of orange production.

When the coefficient is greater than zero, the interaction will be positive. This means the combination of those input factors will increase the yield. When the coefficient is less than zero, the

interaction will be negative. This means that the combination of those input factors will decrease the yield.

If the coefficients of fourth and fifth order can be determined, it would enable the making of a more precise estimation of the orange yield. However, it might not be necessary, depending on the value of lesser order coefficients. Moreover, time and resources are not available for a test beyond the third order.

It is generally believed that any two or more input factors will have an interaction effect (positive or negative) on orange yield, but some factors might have no interaction effects. Therefore the interaction effect among some of the more important factors of orange yield need to be tested so as to provide scientific information of interest to the orange industry. This function is performed in the next chapter.

CHAPTER III

TESTS OF MODEL INTERACTION WITH TREE CENSUS DATA

Description of Orange Production Factors

Data are available on five of the factors postulated in the model. These are rootstock, variety, tree age, location and disease. An analysis of each of these factors is contained in this chapter.

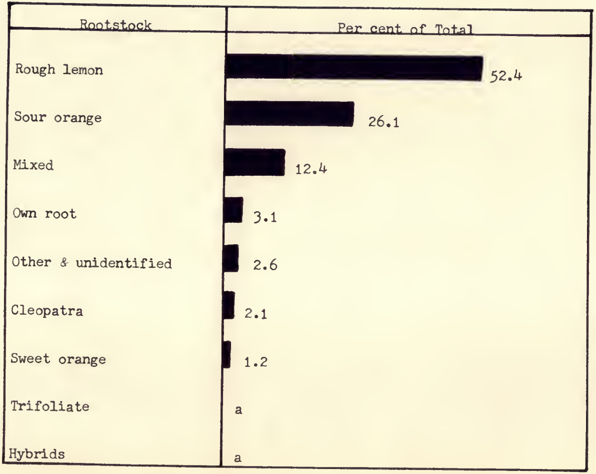
Rootstocks

The Florida orange industry in 1957 utilized nearly 30 million trees[1] for producing its output. The rootstocks for these trees included all of the nine species of stock described previously. Rough lemon was the most widely used rootstock in Florida. It served as the rootstock for 52.4 per cent of all orange trees (Figure 2). The second rootstock in importance was sour orange which made up 26.1 per cent of the total. Mixed rootstocks accounted for 12.4 per cent and ranked third. Own root rootstocks ranked fourth and were 3.1 per cent of the total.

Remaining rootstocks included: others and unidentified, 2.6 per cent; Cleopatra, 2.1 per cent; sweet orange, 1.2 per cent; and trifoliate, less than 0.1 per cent.

---

[1]The total number of orange trees in 1957, according to the Twenty-second Biennial Report of the State Plant Board of Florida, was 31,352,473 in May 1959. This is more than the total tree count of 29,529,576 from the IBM cards used in the study tabulations. The difference in tree numbers is likely due to an adjustment made by the census statistician to account for new plantings.



[a]Less than 0.1 per cent.

Figure 2.--Relative importance of rootstocks used for orange trees in Florida, 1957

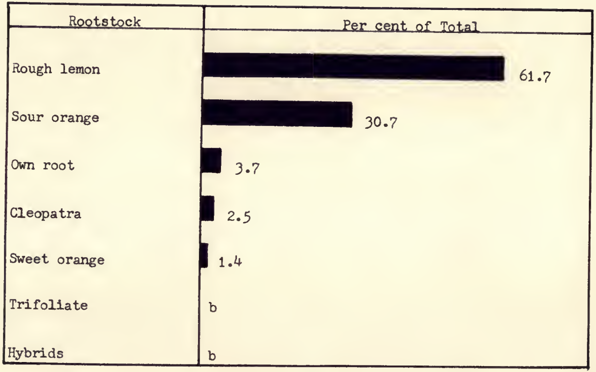
Unclassified rootstocks (mixed plus others and unidentified) accounted for 15.0 (12.4 and 2.6) per cent of the total rootstocks used in orange production in Florida. In analyzing the relative importance of rootstocks in Florida, it is desirable to consider only specified rootstocks. It is probable that the unclassified rootstocks are distributed in the same approximate proportion as the classified rootstocks.

The corresponding percentages of specified rootstocks thus become quite different, but the order of their importance remains the same as when unclassified rootstocks are included. When the unclassified group was excluded, rough lemon rootstock made up 61.1 per cent of the total while sour orange rootstock was 30.7 per cent (Figure 3). The third most important rootstock was own root with 3.6 per cent of the total. The remainder were Cleopatra and sweet orange with 2.5 per cent and 1.4 per cent, respectively, of the total. The proportions of trifoliate and hybrid rootstocks did not change because the numbers of these two rootstocks were relatively small.

Varieties

Varieties of oranges in Florida are generally grouped into three classes based on shipping seasons. These classes are:

Early Oranges: Early oranges are shipped mostly in October and November. Four varieties of oranges are included in this class: Hamlin, Navel, Early Seedy and others.



[a]Excluding unclassified rootstocks.

[b]Less than 0.1 per cent.

Figure 3.--Relative importance of specified rootstocks used for orange trees, Florida, 1957[a]

<u>Mid-season Oranges</u>: Mid-season oranges are shipped in December, January and February. Four varieties are also included in this class: Jaffa, Mid-season Seedy, Seedling and other.

<u>Late Oranges</u>: The shipping period for late oranges is much longer than that for early or mid-season varieties. They are ready for marketing starting in March and ending in July. One of the most important late varieties is the Valencia orange.

There is still another group of orange varieties which is classified as "other oranges." Their strains were not determined by citrus census crews. The "other oranges" are not included in early, mid-season or late oranges. In effect, they belong to a separate class.

According to Florida Citrus Census data, there were about 31 million orange trees in 1957. Of these, early oranges accounted for 22.4 per cent, mid-season oranges 24.4 per cent, late oranges 49.7 per cent and unclassified oranges 3.5 per cent (Figure 4). A classification of orange trees by variety is noted in Figure 5. The Valencia variety accounted for half of all orange trees.

Since major consideration will be given to the specified varieties and it is likely that a high proportion of the unclassified varieties would fall into the same pattern as the known group, a breakdown of the importance of each specified variety as a proportion of all specified varieties is in order (Figure 6). This new relationship shows the Valencia variety as being 52.5 per cent of the total rather than 49.6 per cent. Smaller increases were registered for the other specified varieties.

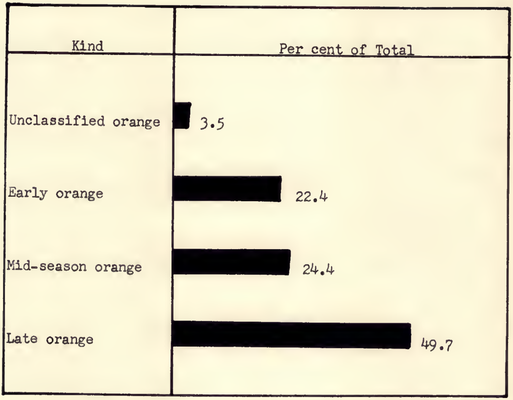


Figure 4.--Relative importance of orange trees by kind in Florida, 1957

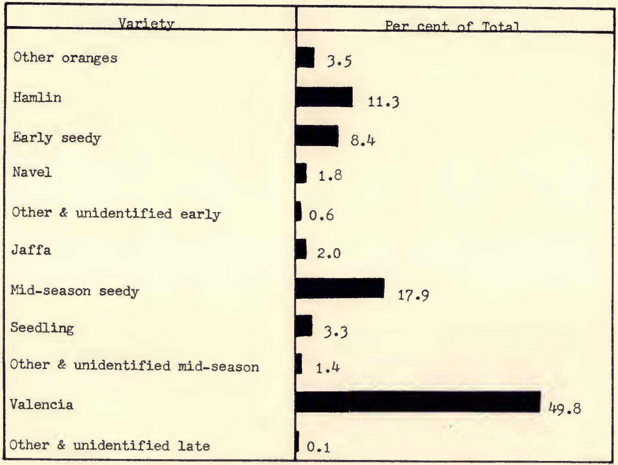
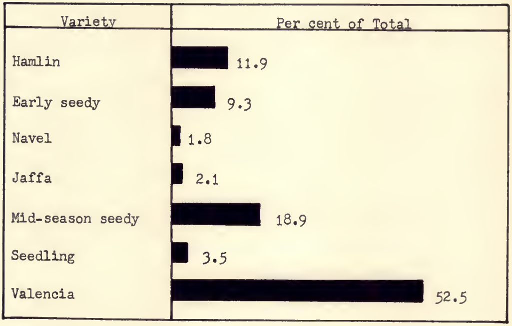


Figure 5.--Relative importance of orange trees by varieties in Florida, 1957



[a]Excluding unnamed and "other" varieties.

Figure 6.--Relative importance of specified orange trees by varieties in Florida, 1957[a]

Tree age

The ages of Florida orange trees were classified into five groups, previously indicated in Chapters I and II. In addition to these groups, another group was called "non-bearing resets." In a bearing grove (tree aged more than four years) any trees less than five years old are considered as non-bearing resets.

The percentage of orange trees in each of these six age groups is shown in Figure 7. A third of all orange trees in 1956 were 26 years of age or older and approximately 40 per cent were under 10 years of age.

Location of orange trees

The locations of Florida orange trees in 1957 are shown in Figure 8. The Upper Interior, which includes three counties, had a third of all the trees. The Lower Interior, which includes seven counties, ranked second with 30.0 per cent of the total number of trees and the West Coast, with eight counties, was third with 17 per cent of the total. The North Fringe, with ten counties, accounted for 10.2 per cent while the East Coast had only 8.8 per cent of the total number within its seven counties.

Diseases of orange trees

Orange trees in Florida are subject to a number of injurious diseases. Nine major diseases were listed and specified in Florida Citrus Census data. A total of about 1.1 million orange trees with these diseases was found during the census period. About 3.8 per cent of all orange trees had one or more diseases. Some of these trees were

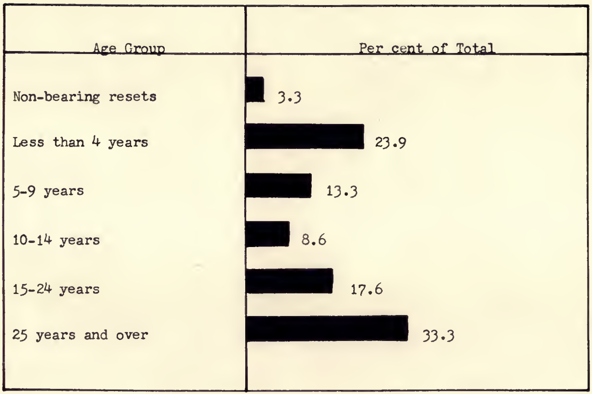


Figure 7.--Relative importance of Florida orange trees by age groups, 1957

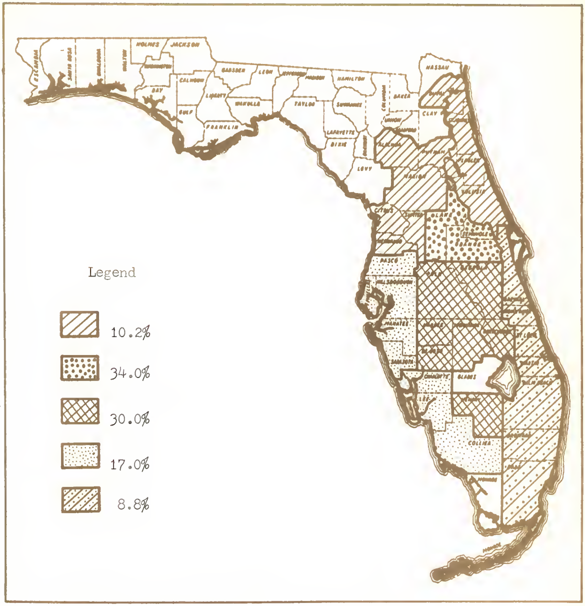
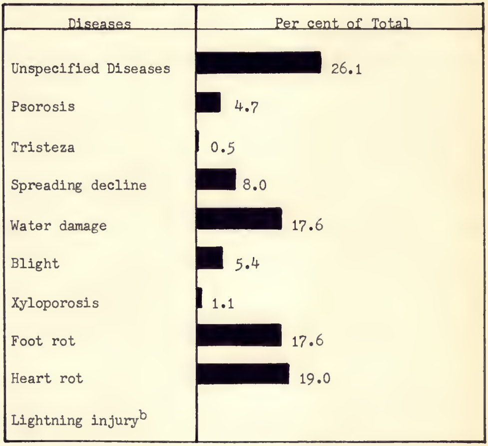


Figure 8.--Distribution areas of Florida orange trees, 1957

declining in production; still others were out of production. No detailed analysis of the degree of disease on trees was made in the census.

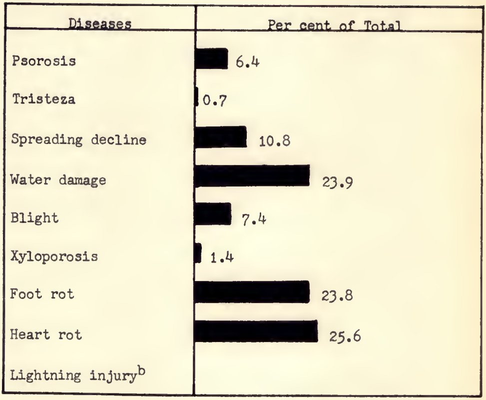
Trees affected by unspecified diseases were the highest in number. They accounted for 26.1 per cent of all diseased trees. The second highest was heart rot with 19.0 per cent. The remainder were: water damage, 17.6 per cent; foot rot, 17.6 per cent; spreading decline, 8.0 per cent; blight, 5.4 per cent; psorosis, 4.7 per cent; xyloporosis, 1.0 per cent; tristeza, 0.5 per cent; and lightning injury, 0.04 per cent (Figure 9). The relative distribution of trees with specified diseases is shown in Figure 10.



[a]Including data only on trees with disease(s) reported.

[b]Less than 0.1 per cent.

Figure 9.--Relative importance of orange tree diseases in Florida, 1957[a]



[a]Excluding unclassified diseases.

[b]Less than 0.1 per cent.

Figure 10.--Relative importance of specified diseases on orange trees in Florida, 1957[a]

Combinations of Specified Factors and Tests of Their Interactions

Various factor combinations were made in this study to test interactions. A three out of five factor combination yields a total of ten sets of combinations. In each set several three way tables were constructed with empirical data. The number of tables in each set was based on the number of kinds or levels of the leading factor of these tables. An example is the combination of varieties by age groups with rootstocks. The leading factor is rootstock of which there are seven specified varieties. That is, there are seven tables of varieties by tree age groups headed by seven specified rootstocks. If locations were the major factor, only five tables would have been constructed because only five locations were included in this study.

The remainder of this section is concerned with an analysis of the combinations of specified factors.

Variety of tree by age group on rootstock.--In this set of combinations there are seven three way tables: variety of tree by age group headed by sour orange rootstock; variety of tree by age group headed by rough lemon rootstock; variety of tree by age group headed by trifoliate rootstock; variety of tree by age group headed by Cleopatra rootstock; variety of tree by age group headed by sweet orange rootstock; variety of tree by age group headed by hybrid rootstock; and variety of tree by age group headed by own root. The data in each table were tested for interaction. Data distribution and test results for two of the combinations are shown in Tables 4 and 5. The test results of those tables not included here are shown in the appendix.

TABLE 4.--Distribution of commercial orange trees on sour orange rootstock classified by varieties and age groups in Florida, 1957[a]

Variety	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
	1,000 trees					
Hamlin	193	102	145	340	238	1018
Early seedy	150	154	109	293	317	1023
Navel	79	68	44	54	18	263
Jaffa	4	8	19	31	17	79
Mid-season seedy	171	131	144	397	695	1538
Seedling	1	1	b	b	1	3
Valencia	575	474	349	769	969	3136
Total	1173	938	810	1884	2255	7060

$X^2 = 189.48$ (significant)

[a]Computation of X^2 done in units of 2,000 trees.

[b]Less than 500 trees.

TABLE 5.--Distribution of commercial orange trees on rough lemon rootstock classified by varieties and age groups in Florida, 1957[a]

Variety	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
	1,000 trees					
Hamlin	198	148	227	529	412	1514
Early seedy	94	179	129	204	385	991
Navel	32	17	9	7	10	75
Jaffa	21	98	71	136	69	395
Mid-season seedy	854	330	120	294	712	2310
Seedling	21	14	1	b	2	38
Valencia	2875	1499	738	991	3024	9127
Total	4095	2285	1295	2161	4614	14450

$X^2 = 696.27$ (significant)

[a]Computation of X^2 done in units of 2,000 trees.

[b]Less than 500 trees.

Variety of tree by location on rootstock.--This set of combinations is similar to the previous set. The only difference between these two sets of combinations is that the factor of age groups in the above tables is replaced by locations. Therefore, seven tables are also included in this set of combinations. Data for two of the most important combinations are shown in Tables 6 and 7.

Age group by location of variety.--Seven specified varieties are included here. In this set of combinations there are seven tables headed by each of the specified varieties. The X^2 values for this set of tests are shown in the appendix. Data on Valencia, mid-season seedy and Hamlin, the three major varieties, are shown in Tables 8, 9, and 10.

TABLE 6.--Distribution of commercial orange trees on sour orange rootstock classified by varieties and locations in Florida, 1957[a]

Variety	Location					
	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - - - 1,000 trees - - - - - - - - - -					
Hamlin	255	251	341	115	92	1054
Early seedy	419	106	446	61	27	1059
Navel	64	38	80	14	75	271
Jaffa	9	10	35	21	5	80
Mid-season seedy	402	123	403	73	586	1587
Seedling	1	2	b	2	..	5
Valencia	465	472	897	221	1139	3194
Total	1615	1002	2202	507	1924	7250

X^2 = 528.05 (significant)

[a]Computation of X^2 done in units of 2,000 trees.

[b]Less than 500 trees.

TABLE 7.--Distribution of commercial orange trees on rough lemon rootstock classified by varieties and locations in Florida, 1957[a]

Variety	Location					
	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - - - 1,000 trees - - - - - - - - - -					
Hamlin	35	254	687	560	5	1541
Early seedy	20	144	340	495	5	1004
Navel	4	19	39	14	2	78
Jaffa	3	38	98	266	1	406
Mid-season seedy	47	380	927	933	41	2328
Seedling	3	1	31	2	b	37
Valencia	343	1934	2795	4044	144	9260
Total	455	2770	4917	6314	198	14654

X^2 = 207.24 (significant)

[a]Computation of X^2 done in units of 2,000 trees.

[b]Less than 500 trees.

TABLE 8.--Distribution of Hamlin orange trees classified by locations and age groups in Florida, 1957[a]

Age Group	Location					
	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - - - 1,000 trees - - - - - - - - - -					
Less than 4 years	100	175	196	72	5	548
5-9 years	22	69	154	58	10	313
10-14 years	24	73	206	124	20	447
15-24 years	83	185	443	306	48	1065
25 years and over	129	91	330	247	26	823
Total	358	593	1329	807	109	3196

X^2 - 116.15 (significant)

[a]Computation of X^2 done in units of 2,000 trees.

TABLE 9.--Distribution of mid-season seedy orange trees classified by locations and age groups in Florida, 1957[a]

Age Group	Location					
	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - - - 1,000 trees - - - - - - - - - -					
Less than 4 years	96	186	581	272	25	1160
5-9 years	48	78	236	139	54	555
10-14 years	17	44	106	56	96	319
15-24 years	64	125	290	188	237	904
25 years and over	344	225	631	567	314	2081
Total	569	658	1844	1222	726	5019

$X^2 = 263.45$ (significant)

[a]Computations of X^2 done in units of 2,000 trees.

TABLE 10.--Distribution of Valencia orange trees classified by age groups and locations in Florida, 1957[a]

Age Group	Location					
	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - - - 1,000 trees - - - - - - - - - -					
Less than 4 years	383	1000	1485	779	135	3782
5-9 years	111	463	807	662	229	2272
10-14 years	57	254	450	335	108	1204
15-24 years	105	355	620	571	455	2106
25 years and over	214	662	1073	2164	539	4652
Total	890	2734	4435	4511	1466	14016

$X^2 = 143.73$ (significant)

[a]Computation of X^2 done in units of 10,000 trees.

Age group by disease of variety.--This set of combinations deals with various aged trees of specified varieties having identified diseases. Each of these tables is headed by a specified variety. Three groups of these relationships are shown in Tables 11, 12, and 13.

Locations by disease of tree age group.--Five tables are included in this set with each headed by a specified age group. Only one table and its X^2 value is illustrated here (Table 14). The X^2 values of those tables not shown are in the appendix.

Locations by rootstock of tree age group.--Specified rootstocks in different locations of various age groups were considered in this set of combinations. Five three way tables were constructed and tested. The result of one of them is noted in Table 15. The X^2 values for the others are noted in the appendix.

Disease by rootstock in various locations.--Five tables were included in this set of combinations. The factor interrelationships of each table were tested; the results are shown in the appendix.

Specified rootstocks in the Lower Interior region had a higher percentage of specified diseases than those in the other regions. The distribution of diseased trees and rootstocks in the Lower Interior region is shown in Table 16.

Disease by variety in various locations.--There were also five tables in this set of combinations. Data analyzed are very similar to those in the preceding table. The only difference is that the rootstocks in the above tables were replaced by specified varieties.

TABLE 11.-- Distribution of diseased trees of Hamlin orange classified by diseases and age groups in Florida, 1957[a]

Diseases	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
	- - - - - - - - - - - - 100 trees - - - - - - - - - - - -					
Psorosis	b	1	8	66	47	122
Tristeza	b	1	1	3	3	8
Spreading decline			3	26	18	47
Water damage	b	19	46	37	31	133
Blight	b	1	3	19	23	46
Xyloporosis		1	16	4	4	25
Foot rot	1	8	17	61	79	166
Heart rot	b	1	3	13	42	59
Lightning injury		b	b	b	b	
Total	1	32	97	229	247	606

$X^2 = 171.67$ (significant)

[a]Computations of X^2 done in units of 100 trees.

[b]Less than 50 trees.

TABLE 12.--Distribution of diseased trees of mid-season seedy orange classified by diseases and age groups in Florida, 1957[a]

Diseases	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
	- - - - - - - - - - - - - 100 trees - - - - - - - - - - - - -					
Psorosis	b	2	4	31	78	115
Tristeza	b	b	1	2	5	8
Spreading decline		b	2	28	114	144
Water damage	2	56	90	187	246	581
Blight	b	1	3	27	113	144
Xyloporosis	b	8	2	1	2	13
Foot rot	1	6	10	95	345	457
Heart rot	b	1	8	78	474	561
Lightning injury	b	b	b	b	b	
Total	3	74	120	449	1377	2023

$X^2 = 485.50$ (significant)

[a]Computations of X^2 done in units of 100 trees.

[b]Less than 50 trees.

TABLE 13.--Distribution of diseased trees of Valencia oranges classified by diseases and age groups in Florida, 1957[a]

Diseases	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
	- - - - - - - - - - - - 100 trees - - - - - - - - - - - -					
Psorosis	b	25	8	55	126	214
Tristeza	2	6	5	6	11	30
Spreading decline	3	5	7	97	471	583
Water damage	13	93	103	341	480	1030
Blight	b	3	7	70	257	337
Xyloporosis	1	27	11	16	8	63
Foot rot	5	27	30	135	468	665
Heart rot	1	8	10	76	448	543
Lightning injury	b	2	b	b	b	2
Total	25	196	181	796	2269	3467

$X^2 = 635.11$ (significant)

[a]Computations of X^2 done in units of 100 trees.

[b]Less than 50 trees.

TABLE 14.--Distribution of diseased trees with the age between 15-24 years classified by diseases and locations in Florida, 1957[a]

Diseases	Location					
	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - - -	- - - - - -	100 trees	- - - - - - - -	- - - - - -	- - - -
Psorosis	17	19	68	49	33	186
Tristeza	2	2	5	6	2	17
Spreading decline			32	404	57	493
Water damage	2	13	60	80	505	660
Blight	3	19	29	82	57	190
Xyloporosis	2	6	5	5	b	18
Foot rot	20	79	77	245	23	444
Heart rot	18	34	24	239	42	357
Lightning injury	b		b	4		4
Total	64	172	300	1114	719	2369

X^2 = 1410.88 (significant)

[a]Computations of X^2 done in units of 100 trees.

[b]Less than 50 trees.

TABLE 15.--Distribution of commercial orange trees with age between 15-24 years classified by locations and rootstocks in Florida, 1957[a]

Location	Rootstock							
	Sour Orange	Rough Lemon	Trifoliate[c]	Cleopatra	Sweet Orange	Hybrids[c]	Own Root	Total
	- - - - - - - - - - - - - 1,000 trees - - - - - - - - - - - - -							
North Fringe	308	27		1	1		b	337
West Coast	207	411		18	6	b	23	665
Upper Interior	643	693		59	29		19	1443
Lower Interior	118	1024	1	19	4		31	1197
East Coast	678	55		b	2		b	735
Total	1954	2210	1	97	42		73	4377

$X^2 = 345.09$ (significant)

[a]Computations of X^2 done in units of 5,000 trees.

[b]Less than 500 trees.

TABLE 16.--Distribution of diseased trees in Lower Interior region classified by diseases and rootstocks in Florida, 1957[a]

Disease	Rootstock							
	Sour Orange	Rough Lemon	Trifoliate[c]	Cleopatra	Sweet Orange	Hybrids[c]	Own Root	Total
	- - - - - - - - - - - - - - 100 trees - - - - - - - - - - - - -							
Psorosis	7	62		b	b	b	b	69
Tristeza	5	4					b	9
Spreading decline	3	554					10	567
Water damage	113	68		1	b		6	188
Blight	5	123		b	b		4	132
Xyloporosis	1	4						5
Foot rot	16	345	b	1	1	b	136	499
Heart rot	11	319	b	b	b	b	205	535
Lightning injury[c]	b	b		b			b	
Total	161	1479		2	1		361	2004

$X^2 = 1137.72$ (significant)

[a]Computations of X^2 done in units of 100 trees.

[b]Less than 50 diseased trees.

Again, the Lower Interior area had more diseased trees than any other location. These data are shown in Table 17.

TABLE 17.--Distribution of diseased trees in Lower Interior classified by diseases and varieties in Florida, 1957[a]

Disease	Variety							
	Hamlin	Early seedy	Navel	Jaffa	Mid-season seedy	Seedling	Valencia	Total
	100 trees							
Psorosis	25	10	1	1	14	b	39	90
Tristeza	1	b	b	1	1	b	8	11
Spreading decline	35	44	b	8	86	10	405	588
Water damage	33	40	1	5	51	6	98	234
Blight	9	10	1	3	40	4	96	163
Xylo-porosis	18	2	b	1	2		19	42
Foot rot	55	47	1	11	195	137	295	741
Heart rot	30	35	1	7	193	206	224	696
Lightning injury[c]	b	b	b	b	b	b	b	b
Total	206	188	5	37	582	363	1184	2565

X^2 = 374.11 (significant)

[a]Computations of X^2 done in units of 100 trees.

[b]Less than 50 trees.

[c]Not included in X^2 test.

Rootstock by variety with disease.--There were nine tables, each of them headed by an identified disease. All of these tables have also been tested (see appendix).

Most of the diseases considered are very important problems of the orange industry. Data on some of the diseases on various rootstocks classified by tree age groups are shown in Tables 18, 19 and 20.

TABLE 18.--Distribution of commercial orange trees with psorosis classified by rootstocks and age groups in Florida, 1957

Rootstock	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
Sour orange	20	299	1148	7009	10649	19125
Rough lemon	67	2419	641	4322	7994	15443
Trifoliate[a]					2	2
Cleopatra		2	48	1248	184	1482
Sweet orange		4	15	114	296	429
Hybrid[a]					1	1
Own root			2	12	664	678
Total	87	2724	1854	12705	19790	37160

$X^2 = 5107.50$ (significant)

[a]Not included in X^2 test.

TABLE 19.--Distribution of commercial orange trees with tristeza classified by rootstocks and age groups in Florida, 1957

Rootstock	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
Sour orange	23	860	688	964	857	3392
Rough lemon	5	29	24	83	429	570
Trifoliate[a]						
Cleopatra[a]				2		2
Sweet orange				7	77	84
Hybrids[a]						
Own root					204	204
Total	28	889	712	1056	1567	4252

$X^2 = 1335.76$ (significant)

[a]Not included in X^2 test.

TABLE 20.--Distribution of commercial orange trees with water damage classified by rootstocks and age groups in Florida, 1957

Rootstock	Age					
	Less than 4 years	5-9 years	10-14 years	15-24 years	25 years and over	Total
Sour orange	1390	17339	17091	45562	45880	127262
Rough lemon	339	1921	3177	8010	11976	25423
Trifoliate[a]						
Cleopatra		40	2030	107	36	2213
Sweet orange		619	9	78	217	923
Hybrids[a]						
Own root		19	17	324	1697	2053
Total	1729	19938	22324	54081	59802	157874

$X^2 = 173.46$ (significant)

[a]No disease reported.

Evaluation of Chi-square Tests

As noted previously, the objective in this phase of the dissertation is to determine whether or not there is some interaction among the various two or three factor combinations of the production model presented in Chapter II. In other words, this study was done to determine whether the coefficients c_i and b_i in model (10) were zero. If any one of the c_i's were zero, then the coefficients of the b_i's for corresponding factors, or the second order coefficients of certain b_i's, need to be tested.

The three way tables presented in this chapter were used to test the c_i's to see if they were zero. The simple chi-square technique was employed in these tests. All X^2 tests were statistically significant. This suggests that any one of these three factor combinations is not arbitrary. For instance, the number of orange trees

of a specified variety budded on sour orange rootstock, one of the oldest stocks in Florida, differed from one variety to another and from one age group to another. The proportion of Valencia orange trees in each age group was: less than 4 years--18.4 per cent; 5 to 9 years--15.1 per cent; 10 to 14 years--11.1 per cent; 15 to 24 years--24.5 per cent; and 25 years and older--30.9 per cent. Sour orange rootstocks used by Hamlin--an early orange, or mid-season seedy--a mid-season orange, had the same tendency of distribution; that is, the percentage of trees in the age groups 5 to 9 and 10 to 14 was lower than in other groups. The likely reason for this is the decreased recent use of sour orange as a rootstock. Sour orange rootstock is very susceptible to tristeza, one of the bud-transmissible diseases which has caused the loss of several million trees in the last twenty years in South America. Because of a possible outbreak of tristeza in Florida, it is not considered advisable to use sour orange as a stock. However, the percentage of the trees less than 4 years was higher than the proportion in the age group of 5 to 9 years or 10 to 14 years. One reason for continued heavy plantings of sour orange rootstock is that no outbreak of tristeza has yet occurred in Florida. Another reason is that there is no really satisfactory substitute rootstock which is suitable for the wet, heavy soils of Florida.

Another example is that the extent of water damage was not related to tree ages. In some cases older trees suffered more water damage than young trees. This seemingly contrary situation might be explained in that these rootstocks were most probably planted in places

where conditions of drainage were poor. On the other hand, the number of trees on specified rootstocks which suffered from psorosis, a bud-transmissible disease, differed from one age group to another. Old trees suffered more than young trees. This might be explained by the failure of this virus disease not to occur when trees were young.

All tests were statistically significant, and the effect of one factor is interrelated with the other two. For example, it is misleading to discuss tristeza without specifying the rootstock and age. This applies to all other factor combinations tested.

CHAPTER IV

SOME ECONOMIC INTERPRETATIONS

Some of the more important interactions presented in earlier chapters are reconsidered here for further economic evaluation with regard to their future effect of Florida orange production. These are disease by rootstock interactions; the most important is tristeza on sour orange rootstock. The other diseases are psorosis and xyloporosis.

Of the 607,400 trees with specified diseases, 37.6 per cent were on sour orange rootstock; 42.3 per cent on rough lemon rootstock; 0.8 per cent on Cleopatra rootstock; 0.8 per cent on sweet orange rootstock; and 18.5 per cent on own root. Diseased trees on hybrid and trifoliate rootstocks each numbered less than 0.1 per cent of the total. However, these percentages do not indicate that one rootstock is better than another or that trees on certain rootstocks are less susceptible to disease than others because the total number of trees with specific rootstocks differed.

Trees grown on own roots had the highest proportion of diseases--12.2 per cent. Hybrid stock had 4.9 per cent diseased trees and sour orange rootstock 3.1 per cent. The remainder were: rough lemon, 1.7 per cent; sweet orange, 1.4 per cent; trifoliate, 0.9 per cent; and Cleopatra, 0.8 per cent.

Since these percentages included only identified diseases, they would show a minimum number of diseased trees when used to estimate the number of trees in groves where rootstocks are known. For example, in an average grove on sour orange rootstocks with a total of 10,000 trees, about 310 trees would likely have identifiable diseases. In fact, there might be more than 310 diseased trees, but the specific diseases would probably not be recognized. However, if rootstock and diseases were known, the number of diseased trees within groves can be approximated by using these relationships.

Percentages of specified diseases on trees with identified rootstocks were: psorosis, 6.1 per cent; tristeza, 0.7 per cent; spreading decline, 11.4 per cent; water damage, 26.0 per cent; blight, 7.7 per cent; xyloporosis, 0.5 per cent; foot rot, 22.4 per cent; heart rot, 25.0 per cent; and lightning injury, 0.1 per cent.

Outbreaks of any one of these diseases could result in serious losses in orange production. Several are of such a serious nature as to affect the entire future of the Florida orange industry. Therefore, the implications of several important diseases will now be considered.

Diseases such as tristeza, psorosis and xyloporosis are bud-transmissible diseases. Although the percentages of these diseases are currently relatively small (see page 34), the potential damage from a serious outbreak is astounding. Another source of loss to the orange industry is water damage.

Certain characteristics of these diseases (or disease-related conditions) will be discussed in this chapter. The implications to the orange industry of an outbreak of these diseases will also be analyzed.

Tristeza.--Although tristeza primarily affects trees on sour orange rootstock, it also affects those on other rootstocks to a lesser extent. The data shows that about 4,300 trees on specified rootstocks had tristeza. Of these, 79.8 per cent were on sour orange rootstock. The remainder were distributed as follows: 13.4 per cent on rough lemon rootstock; 4.8 per cent on own root; 2.0 per cent on sweet orange stock; and 0.04 per cent on Cleopatra. No tristeza was found on trees budded to trifoliate and hybrid rootstocks. The ratio of tristeza diseased trees to healthy trees of specified rootstocks also shows that trees on sour orange rootstocks were more susceptible to tristeza[1] than trees on other rootstocks.

Tristeza is an infectious disease which acts quickly to destroy citrus trees. It has destroyed approximately 20 million trees in South America during the past 20 years. Meanwhile, the citrus industry in South Africa, Australia and some citrus areas of the United States have also suffered from its ravages.[2]

Until recently Florida was still thought to be one of the four remaining citrus areas in the world free from infection spread by the

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[1]The ratios of tristeza diseased trees to healthy trees of specified rootstocks were:

Sour orange	4.65:10,000
Rough lemon	0.38:10,000
Cleopatra	0.35:10,000
Sweet orange	2.46:10,000
Own root	2.22:10,000

[2]L. C. Knorr et al, Handbook of Citrus Diseases in Florida, Florida Agricultural Experiment Station Bulletin 587, June 1957, p. 133.

tristeza[3] virus. However, the natural spread of the tristeza virus, evident in Orange and Lake counties a few years ago, has now been detected in ten of Florida's largest citrus producing counties.[4] The Florida Division of Plant Industry has issued a warning regarding the use of sour orange stock in citrus planting.

Tristeza occurred in all age groups of trees, but the older age group of trees had the higher percentage of this disease. Of the total of 4,300 trees affected with tristeza, 0.7 per cent were less than 4 years. The remainder were distributed as follows: 17.7 per cent between 5 to 9 years; 14.4 per cent between 10 to 14 years; 25.8 per cent between 15 to 24 years; and 41.3 per cent 25 years and older. The highest ratio of tristeza diseased trees to healthy trees was the tree age between 10 to 14 years and lowest was the tree age less than 4 years.[5]

The percentage of tristeza diseased trees distributed in various areas was as follows: North Fringe, 21.4 per cent; West Coast, 14.0 per cent; Upper Interior, 33.6 per cent; Lower Interior, 21.5 per cent; and East Coast, 9.5 per cent. However, the North Fringe had the highest

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[3] Ibid.

[4] Florida Department of Agriculture, Division of Plant Industry News Bulletin, Vol. 4, No. 2, April 1962.

[5] Ratios of tristeza diseased trees to healthy trees in various age groups were:

Less than 4 years	0.5:1,000,000
5-9 years	256:1,000,000
10-14 years	323:1,000,000
15-24 years	241:1,000,000
25 years and over	201:1,000,000

ratio of trees with tristeza to healthy trees and the Lower Interior had the lowest ratio.[6]

Psorosis.--Psorosis accounted for 6.4 per cent of all identified diseases on trees of specified rootstocks. Of these, 51.5 per cent were on sour orange rootstock. The remainder were: 41.6 per cent on rough lemon rootstock; 4.0 per cent on Cleopatra rootstock; 1.8 per cent on own root; 1.2 per cent on sweet orange rootstock; and only several diseased trees on trifoliate and hybrid rootstocks.

The ratio of psorosis diseased trees to healthy trees on specified rootstocks shows that relatively more of the diseased trees were on sour orange and Cleopatra stock[7] than on trees of other specified rootstocks.

From the point of view of tree ages, only 0.2 per cent of trees with psorosis were less than four years. The remainder were: 7.3 per cent between 5 to 9 years; 5.0 per cent between 10 to 14 years; 34.2 per cent between 15 to 24 years; and 53.3 per cent 25 years and over.

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[6]Ratios of tristeza diseased trees to healthy trees in various areas were:

North Fringe	3.6:10,000
West Coast	1.4:10,000
Upper Interior	1.8:10,000
Lower Interior	1.2:10,000
East Coast	1.7:10,000

[7]The ratios of psorosis diseased trees to healthy trees of specified rootstock were:

Sour orange	2.6:10,000
Rough lemon	1.0:10,000
Cleopatra	2.6:10,000
Sweet orange	1.3:10,000
Own root	0.7:10,000

Trees less than four years had a lower ratio than any other age group.[8]

Psorosis diseased trees on specified rootstocks were distributed among five areas as follows: 15.5 per cent in North Fringe; 14.0 per cent in West Coast; 33.1 per cent in Upper Interior; 18.6 per cent in Lower Interior; and 18.8 per cent in East Coast. When considering the ratio of diseased trees to healthy trees by areas, the East Coast had the highest ratio of any area.[9]

Xyloporosis.--Xyloporosis is also a bud-transmitted disease that affects various species of citrus.[10] But it has been controlled very well in this state. Only about 3,000 xyloporosis diseased trees were found on the specified rootstock trees during the Florida citrus census period. Of these 19.7 per cent were on sour orange stock; 78.4 per cent on rough lemon rootstock; 1.7 per cent on sweet orange rootstock; 0.2 per cent on Cleopatra rootstock; and less than 0.1 per cent

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[8]The ratios of psorosis diseased trees to healthy trees in age groups were:

Less than 4 years	1.41:1,000,000
5-9 years	784:1,000,000
10-14 years	840:1,000,000
15-24 years	2901:1,000,000
25 years and over	2536:1,000,000

[9]The ratios of psorosis diseased trees to healthy trees in various areas were:

North Fringe	2.3:10,000
West Coast	1.2:10,000
Upper Interior	1.5:10,000
Lower Interior	0.9:10,000
East Coast	3.0:10,000

[10]L. C. Knorr et al., op. cit., p. 147.

on own root. No xyloporosis was found on trifoliate and hybrid rootstocks. The ratio of xyloporosis diseased trees to healthy trees on various rootstocks[11] indicates that trees on rough lemon and sweet orange rootstocks were more susceptible to xyloporosis than trees on other specified rootstocks.

An analysis of xyloporosis diseased trees by age groups showed that only 3.8 per cent were less than 4 years. One-third or 34.5 per cent of xyloporosis diseased trees were between 5 to 9 years. The remainder were: 28.0 per cent between 10 to 14 years; 19.0 per cent between 15 to 24 years; and 14.7 per cent 25 years and over. The highest ratio of diseased trees to healthy trees was the age group between 10 and 14 years old. The lowest was the age group less than 4 years.[12]

Xyloporosis diseased trees were distributed in the various areas as follows: 12.3 per cent in North Fringe; 55.4 per cent in West Coast; 16.7 per cent in Upper Interior; 14.1 per cent in Lower Interior; and 1.5 per cent in East Coast. The East Coast had the lowest ratio of

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[11]The ratios of xyloporosis diseased trees to healthy trees of specified rootstocks were:

Sour orange	8.5:100,000
Rough lemon	16.5:100,000
Cleopatra	0.9:100,000
Sweet orange	15.2:100,000
Own root	0.1:100,000

[12]The ratios of xyloporosis diseased trees to healthy trees by age group were:

Less than 4 years	1.9:100,000
5-9 years	31.1:100,000
10-14 years	39.8:100,000
15-24 years	13.6:100,000
25 years and over	5.9:100,000

diseased trees to healthy trees and the West Coast had the highest.[13]

Water damage.--Water damage accounted for 26 per cent of all identified diseases on trees with specified rootstocks. Most of the water damaged trees were on sour orange rootstock; they made up 81 per cent of the total. The remainder were: rough lemon, 16.1 per cent; Cleopatra, 1.4 per cent; sweet orange, 0.6 per cent; and own root, 1.3 per cent. No water damage on trifoliate and hybrid rootstock was reported.

The ratio of water damaged trees to healthy trees of specified rootstocks shows that sour orange trees had a higher ratio of water damage than trees on any other rootstock.[14]

Water damage occurred in all age groups of orange trees. The younger age groups had fewer water damaged trees than the 10 to 14 and 15 to 24 year groups.[15]

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[13]The ratios of xyloporosis diseased trees to healthy trees by areas were:

North Fringe	1.5:10,000
West Coast	4.1:10,000
Upper Interior	0.7:10,000
Lower Interior	0.6:10,000
East Coast	0.2:10,000

[14]The ratios of water damaged trees to healthy trees of specified rootstocks were:

Sour orange	17.4:1,000
Rough lemon	1.7:1,000
Cleopatra	3.9:1,000
Sweet orange	2.7:1,000
Own root	2.2:1,000

[15]The ratios of water damaged trees to healthy trees in various age groups were:

Less than 4 years	3.2:1,000
5-9 years	61.9:1,000
10-14 years	115.7:1,000
15-24 years	152.5:1,000
25 years and over	107.4:1,000

The East Coast had the highest ratio of water damaged trees to healthy trees and the North Fringe had the lowest ratio of water damage.[16] It is clear that the East Coast had serious water damage problems when compared to other areas.

Effect of Budwood Program

The citrus budwood program of Florida, started in 1953, is directed at producing virus-free citrus budwood. The budwood program was: true ?

> originally intended to assist growers and nurserymen in obtaining a source of budwood trees to type and free of bud mutations and virus diseases. It now includes the certification of seed used for rootstocks and the development and testing of nucellar strain of commercial importance. Activities of the certification group includes routine screening, inspection and testing of possible virus-free bud and seed sources entered by participants in the program, the regulation, inspection, and labeling of registered nursery stock, and the supervision of planting of scion groves to be used as future sources of budwood.[17]

Virus testing is limited to the transmissibility of psorosis, xyloporosis and exocortis viruses for they are affected only by means of living tissue or almost entirely by contaminated budwood. Tristeza is bud-transmitted, but also is known to be spread by insects. Therefore, no certification for freedom from this disease has ever been

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[16]The ratios of water damaged trees to healthy trees in various areas were:

North Fringe	7.8:1,000
West Coast	15.6:1,000
Upper Interior	15.9:1,000
Lower Interior	24.3:1,000
East Coast	509.1:1,000

[17]State Plant Board of Florida, Twenty-second Biennial Report for the Period of July 1, 1956-June 30, 1958, Gainesville, Florida, May 1, 1959, p. 47.

attempted in the budwood program because it is believed that control of budwood cannot prevent tristeza infection in trees. However, it has been the policy of the program to test all present candidate trees for tristeza.[18]

Since its inception in 1953 the budwood program has met with industry favor. In 1957 trees under 4 years of age had only 19 and 14 diseased trees, xyloporosis and psorosis, respectively, per million healthy trees. However, trees from 5 to 9 years of age planted before the budwood program, had 311 xyloporosis and 784 psorosis diseased trees, respectively, per million healthy trees. That is, the number of psorosis diseased trees in the 5 to 9 year age group was 56 times larger than that in the less than 4 year age group. For xyloporosis diseased trees, the older age group was 16 times larger than the younger age group. Although the entire credit for this development might not all be attributable to the budwood program, it was sufficient to encourage the citrus industry to expand this program.

Considerations of Orange Yield Losses

Tristeza, psorosis, xyloporosis and water damage have been discussed above. The first three diseases are infectious diseases and the last one, while not really a disease, has somewhat the same effect as a disease. All of these bear important implications relative to the future well-being of the Florida citrus industry.

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[18]State Plant Board of Florida, Twenty-third Biennial Report for the Period of July 1, 1958-June 30, 1960, p. 26.

According to the Florida Citrus Tree Census data, 30.4 per cent or about 8 million orange trees with identified rootstocks were on sour orange rootstock. If a severe infection of tristeza were to occur in Florida, it would most probably kill all of the trees on sour orange rootstock. Thus, almost a third of the orange production in Florida would be wiped out. The proportion of trees on sour orange rootstock, classified by age groups and areas, is shown in Table 21.

TABLE 21.--Proportion of all Florida orange trees with specified rootstocks which were budded on sour orange rootstock, by age groups and areas, 1957

Age Group	North Fringe	West Coast	Upper Interior	Lower Interior	East Coast	Total
	- - - - - - - - -		per cent	- - - - - - - - -		
Non-bearing reset	86.1	27.2	32.1	7.9	84.3	33.5
0-4 years	47.4	24.4	13.8	9.0	63.7	20.5
5-9	71.4	25.3	22.7	8.6	79.6	27.7
10-14 years	73.2	37.6	34.0	10.5	90.6	35.2
15-24 years	91.1	31.0	44.5	9.8	92.1	44.6
25 years and over	88.4	16.5	33.0	3.6	87.3	31.1

This indicates that, if a severe infection of tristeza were to occur in Florida and the trees on sour orange were wiped out, then the tree losses would be 33.5 per cent of all non-bearing reset trees; 20.5 per cent of all trees less than 4 years; 27.7 per cent of all trees between 5 to 9 years; 35.2 per cent of all trees between 10 to 14 years; 44.6 per cent of all trees between 15 to 24 years; and 31.1 per cent of all trees above 25 years.

The North Fringe and East Coast areas would lose more trees than others. For instance, the North Fringe would lose 91.1 per cent of all trees between 15 and 24 years old and the East Coast would lose 92.1 per cent. However, in the same age group of trees, only 9.8 per cent would be lost in the Lower Interior.

The value of the loss of fruit alone in one year would be tremendous. For example, if the average yield per tree on sour orange rootstock in 1962 were 3 boxes, the total box loss in the event that these trees were all killed would be about 29.9 million boxes.[19] At an on tree price of $2.00 per box, this would be a loss of $59.8 million in foregone grower sales. However, this does not include indirect losses, such as those of packing house workers, processors, transportation industries and other related businesses. Losses would certainly disrupt or wreck many of those businesses dependent on the orange industry.

A tree injured by tristeza would most likely die quickly.[20] Thus, the loss would be for a period of many seasons rather than for only one. Therefore, losses would be even more than those estimated above. Fortunately, tristeza has not had an outbreak to date in Florida. It accounted for only about 0.7 per cent of all identified diseases on specified rootstock trees.

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[19]Based upon a total yield of 104 million boxes in the 1961-62 season.

[20]Florida State Department of Agriculture, <u>Citrus Industry of Florida</u>, Bulletin No. 2, Tallahassee, Florida, May 1960, p. 134.

An examination of what would happen to specific varieties in the event of a severe outbreak of tristeza is now in order. As indicated before, 30.4 per cent of specified orange trees were on sour orange rootstock. The distribution by varieties was as follows: Hamlin, 14.3 per cent; early seedy, 14.6 per cent; Navel, 3.7 per cent; Jaffa, 1.1 per cent; mid-season seedy, 21.7 per cent; seedling, 0.04 per cent; and Valencia, 44.5 per cent.

Percentages of each specified variety of orange trees were presented in Table 7. All of the specified varieties accounted for 94.5 per cent of all orange trees and the remaining varieties were not identified. This indicated that, if the orange yield were 104 million boxes in the 1961-62 season, approximately 98.3 million boxes were produced by the specified varieties.

Among all of the specified varieties, Hamlin accounted for 11.9 per cent and early seedy for 9.3. The others were: Navel, 1.8 per cent; Jaffa, 2.1 per cent; mid-season seedy, 18.9 per cent; seedling, 3.5 per cent; and Valencia, 52.5 per cent.

This analysis provides a basis for determining the percentage crop losses of each specified variety in case of a severe outbreak of tristeza in Florida. Since trees on sour orange rootstocks accounted for 30.4 per cent of the total, about 29.9 out of 98.3 million boxes of oranges were produced on trees with these rootstocks. The percentage loss of each specified variety is shown in Table 22.

This indicates that, if a severe outbreak of tristeza were to occur in Florida, the orange yield of each specified variety would decrease 36.8 per cent for Hamlin; 47.8 per cent for early seedy; 63.1

per cent for Navel; 16.0 per cent for Jaffa; 34.9 per cent for mid-season seedy; 2.9 per cent for seedling; and 25.8 per cent for Valencia.

TABLE 22.--Percentage of orange yield from each specified variety on sour orange trees, Florida, 1957

Variety	Proportion of total on sour orange trees	Yield of trees on sour orange rootstock	Proportion of all orange trees	Total yield on all rootstock	Proportion of total yield from sour orange trees
	Per cent	Million boxes	Per cent	Million boxes	Per cent
Hamlin	14.3	4.30	11.9	11.70	36.8
Early seedy	14.6	4.37	9.3	9.14	47.8
Navel	3.7	1.11	1.8	1.76	63.1
Jaffa	1.1	0.33	2.1	2.06	16.0
Mid-season seedy	21.7	6.49	18.9	18.58	34.9
Seedling	0.04	0.01	3.5	3.44	2.9
Valencia	44.5	13.31	52.5	51.61	25.8

Water damage is not an infectious disease. But, since the percentage of water damage was one of the highest among all identified diseases on specified rootstocks, it is appropriate to consider orange yield losses due to water damage. Of the 31 million orange trees in Florida, 30.4 per cent were budded on sour orange rootstock. Therefore, the total number of trees on sour orange stock would be 9.4 million. If 1.7 per cent of these trees suffered water damage, then about 164,000 trees would have decreased yields.

Suppose the normal average orange yield per tree was 3 boxes and on tree price was \$2.00 per box. If average losses per tree were only two-thirds of the normal average yields, then the total losses on sour orange trees alone would be about \$650,000 a year.

The estimated value of these losses is based upon a situation where the price per box does not change with a change in supply. However, it is believed that the demand for oranges is inelastic; that is, as the supply of oranges goes down, the price goes up more than proportionally. The total income from the sale of oranges would likely rise, within certain ranges, with a decrease in supply. A study by Fox showed that a 1 per cent change in supply would result in an opposite change in price of 1.61 per cent.[21] A study done in supermarkets by Godwin indicated that the demand for oranges in retail food markets was inelastic.[22] Further evidence of a probable inelastic demand for oranges is that, in recent years, cash receipts from marketings have decreased when supplies have increased.[23] No recent coefficient of demand elasticity for Florida oranges at the grower level is now available. Thus the loss values cited previously are likely overestimates. It is recognized that a gain in revenue for the industry resulting from lower supplies does not allow any compensation for grove operators who sustain total losses.

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[21]Karl A. Fox, The Analysis of Demand for Farm Products, United States Department of Agriculture, Technical Bulletin No. 1081, Washington, D. C., 1953, p. 65.

[22]Marshall R. Godwin, Customer Response to Varying Prices for Florida Oranges, Florida Agricultural Experiment Station, Bulletin 508, December 1952, p. 16.

[23]Florida Crop and Livestock Reporting Service, p. 37.

The Relation of Tree Age to Yields

Tree age and yield relationships for early oranges and late oranges were developed by Kelly.[24] For early oranges, it was indicated by $Y = 0.12724 + 0.35648X - 0.00447X^2$ and for late oranges it was indicated by $Y = -1.04847 + 0.41406X - 0.00583X^2$. Kelly also developed tree age and yield relationships for mid-season oranges, but it is not applicable to this study. For the purpose of estimation, the age and yield relationship of early oranges will also be used to estimate the yield of mid-season oranges because it is believed that the variation between the two types is very small.

It is recognized that orange yields are closely related to tree ages.[25] As the tree age increases, the orange yield also increases. The data in Table 23 provide a sufficient basis for estimating the percentage yield changes of various specified varieties as the tree age increases.

The average age of each variety is: early oranges, 22.75 years; mid-season oranges, 27.37 years; and late oranges, 23.87 years.

The total number of non-bearing trees in 1961 was 13.6 million trees, including 6.6 million early and mid-season orange trees and 6.9 million late orange trees. A weighted average age of bearing early and mid-season oranges gives an average age of those two varieties of 25.28 years.

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[24]Bruce W. Kelly, "A Method of Forecasting Citrus Production in the State of Florida," Ph.D. Dissertation, University of Florida, August 1953.

[25]Zach Savage, <u>Citrus Yield per Tree by Age</u>, Florida Agricultural Extension Service Economic Series 60-8, November 1960.

TABLE 23.--Distribution of orange trees by varietal and age groups, Florida, 1961[a]

Age Group	Variety					
	Early Orange		Mid-season Orange		Late Orange	
	No. of Trees	Pct. of Total	No. of Trees	Pct. of Total	No. of Trees	Pct. of Total
	(1000)		(1000)		(1000)	
5-9 yrs.	971.9	19.18	611.6	9.88	2290.8	17.59
10-14 yrs.	498.5	9.84	677.6	10.95	2043.0	15.69
15-24 yrs.	1749.3	34.51	1390.0	22.45	2922.7	22.44
25 years and over	1848.6	36.47	3511.6	56.72	5767.9	44.28
Total	5068.3	100.00	6190.8	100.00	13024.4	100.00

[a]Variety of orange trees by age groups based upon the citrus tree survey. Florida Crop and Livestock Reporting Service, October 30, 1961.

According to the Florida Crop and Livestock Reporting Service data, early and mid-season oranges will produce a total of 51 million boxes and late oranges 47 million boxes in the 1961-62 season.[26]

Based upon the information above and on the formulae developed by Kelly, future orange yields can be predicted.

Orange yields in the 1966-67 season will first be estimated. The increase in yield five years hence which results from the increase in bearing surface due to the change in average age is estimated. Then an estimate is made of the number of boxes from

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[26]USDA Statistical Reporting Service, Field Operations Division, Orlando, Florida, May 11, 1962.

non-bearing trees. The percentage yield increase for early and mid-season orange five years later would be:

$$Y = 0.12724 + 0.35648X - 0.00447X^2$$

$$\frac{dy}{dx} = 0.35648 - 0.00894X \text{ or}$$

$$dy = (0.35648 - 0.00894X)\ dx$$

The average age of early and mid-season orange is about 25 years. The average yield of 25 year old early orange trees is 6.245 boxes per tree and late orange trees is 5.002 boxes per tree.[27] It is assumed that 25 year old early and mid-season orange trees produce an average of 6 boxes per tree. This is based on a continued upward trend in yields per tree of a given age.

The percentage increase in yield of early and mid-season orange trees over a five-year period would be:

$$\frac{dy}{y} = \frac{0.6649}{6} = 0.1108 \quad \text{or } 11.1\% \text{ increase}$$

$$\text{where } dy = (0.35648 - 0.00894X\ 25)\ X5$$

The percentage yield increase for late oranges over a five-year period would be:

$$Y = -1.04847 + 0.41406X - 0.00583X^2$$

$$\frac{dy}{dx} = 0.41406 - 0.01166X \quad \text{or}$$

$$dy = (0.41406 - 0.01166X)\ dx$$

As indicated above, the average age of late orange trees is about 24 years and the average yield of 25 year old late orange trees

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[27]Kelly, op. cit., pp. 4-15.

is about 5.5 boxes per tree.[28] Then the percentage increase in yield of late oranges over a period of five years would be:

$$\frac{dy}{y} = \frac{0.6711}{5.5} = 0.1220 \quad \text{or} \quad 12.2\% \text{ increase}$$

where $dy = (0.41406 - 0.01166x\ 24)\ X5$

It is estimated that the bearing orange trees of 1961 will produce 116 million boxes of fruit in the 1966-67 season.

However, the non-bearing trees of 1961 will have become bearing trees by the 1966-67 season. Suppose the average age of these trees was seven years old in 1966-67 season and the young early and mid-season trees will produce 2.2 boxes per tree and late oranges will produce 1.7 boxes per tree. Then the young trees would produce 14.5 and 11.8 million boxes or early and mid-season oranges and of late oranges, respectively. Therefore, the total orange yield would be 142.4 million boxes in the 1966-67 season. This estimate is based upon the assumption that there will be no trees planted or lost during this period.

By the 1971-72 season the yield of bearing trees will have increased 18.5 per cent and the non-bearing trees of 1961 will have an average age of 12 years. If the average yield of 12 year old early and mid-season trees was 3.5 boxes per tree and late oranges was 3 boxes per tree, the total orange yield would be 167.2 million boxes in 1971-72 season.

Many economic interpretations can be derived from the results of the tests of the various factor interactions made in the preceding

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[28] *Ibid.*

chapter. However, because of time limitations, it was necessary to restrict the discussion of this chapter to economic interpretations of some of the more important interactions. Specifically, this discussion has included the interactions of disease and rootstock; variety and tree age and their effects; and projections of expected future production. The effect of the budwood program has also been considered.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study has been to analyze data which can provide a basis for evaluating the importance of tree age, rootstock, variety, disease and location of orange trees to the economic welfare of the Florida orange industry. Specifically, the following items were analyzed in this dissertation: (1) a theoretical production model showing the interrelations of various productive factors was developed, (2) the significances of various factor interrelations were determined and tested, and (3) some economic interpretations of the implications of various aspects of the tree count data were made.

Each factor studied was subdivided into several classifications such as age groups, varieties, etc. Only specified factors with distinguishable characteristics were chosen for detailed analysis since it was not possible to determine the attributes of those factors not classified or named.

The major source of the data used in this study was the Florida Citrus Tree Count Census. This census, started in the fall of 1954 and completed in the fall of 1957, was done by the State Plant Board in cooperation with other agencies.

A theoretical production model was developed for utilizing the citrus census data. This model included five factors and their second and third order combinations. No fourth or fifth order combinations

were included. The most important were found to be the third order combinations, i.e., variety of tree by age group on rootstock; variety of tree by location on rootstock; age group by location of variety; age group by disease of variety; location by disease of age group; location by rootstock of age group; disease by rootstock in location; disease by variety in location; rootstock by variety with disease; and rootstock by age group with disease. These combinations, except the set of rootstock by variety with disease (data were not available) were tested by use of the chi-square technique. The results of these tests showed that all combinations were statistically significant.

This indicated that any three factor combinations differed from the others. For example, a particular rootstock, say sour orange, adapted to various varieties in the same location and the number of such rootstock trees, differed from one variety to another. Meanwhile, for a particular rootstock, again say sour orange, adapted to the same variety but a different location, the number of trees on such rootstocks also differed from one location to another. As another example, let us suppose that, in the North Fringe area, the number of trees of a particular rootstock which suffered from various diseases differed from one disease to another or, in the same location, the number of trees with particular diseases also differed from one rootstock to another. This suggests that, if any two factors are known, the orange industry or individual grower could select or determine the third factor which would either result in more productivity or result in fewer losses from diseases.

The economic interpretations presented in this study included two phases: the estimation of orange yield losses from various disease conditions and estimation of orange yield increases as tree ages and bearing surfaces increase.

This study showed that, if tristeza were to occur in a serious outbreak, a loss of about 8 million trees budded on sour orange rootstocks would be sustained. Trees on this rootstock make up about one-fourth of the orange trees in Florida

Orange yield losses of specified varieties would be: Hamlin, 36.8 per cent; early seedy, 47.8 per cent; Navel, 63.1 per cent; Jaffa, 16.0 per cent; mid-season seedy, 34.9 per cent; seedling, 2.9 per cent; and Valencia, 25.8 per cent. The total value of loss of fruit alone in one year would be $59.8 million in foregone grower sales. This estimation is based upon total orange yield in 104 million boxes a year and at an on tree price of $2.00 per box.

A large number of trees suffered loss from water damage during the period of the Florida citrus census. If the percentage of water damaged trees in this period were considered as a normal situation, about 164,000 trees budded on sour orange rootstock would have decreased yields each year. The annual value of the loss of fruit alone would be about $650,000. Some of the trees on other rootstocks also suffered from water damage but their loss was not included in this estimate.

It has been recognized that, as tree age increases, the orange yield per tree also increases, but the percentage of increased yields differ from one variety to another. This study showed that, with an increase in tree age each five years, the yield per tree of early and

mid-season oranges will increase 11.1 per cent and late oranges will increase 12.2 per cent. With a ten year increase in tree age, the yield of present bearing trees will increase an average of 18.2 per cent. This gives an estimated total orange yield of 142.4 million boxes in the 1966-67 season and of 167.2 million boxes in the 1971-72 season.

Some suggestions are offered with respect to future study. If possible, orange yield data from a sample of groves reporting should be collected as a part of the citrus census to provide valuable information for future study.

Further attempts to build an up-to-date production function for each specified variety should be fruitful. By so doing, estimates of future total orange yield for each variety yield could be made more precisely.

APPENDIX

TABLE 24.--Summary of chi-square test of varieties by age groups on rootstocks

Variable	Chi-square	d.f.	Probability
Varieties by age groups on:			
Sour orange	189.485 x 2000	24	0.001
Rough lemon	696.267 x 2000	24	0.001
Trifoliate[a]			
Cleopatra[b]	195.469 x 500	20	0.001
Sweet orange	159.854 x 500	24	0.001
Hybrids[a]			
Own root[c]	423.574 x 100	20	0.001

[a]Not included in X^2 test.

[b]"Seedling" not included in the X^2 test.

[c]"Navel" not included in the X^2 test.

TABLE 25.--Summary of chi-square test of varieties by locations on rootstocks

Variable	Chi-square	d.f.	Probability
Variety by location on:			
Sour orange	528.051 x 2000	24	0.001
Rough lemon	207.237 x 2000	24	0.001
Trifoliate[a]			
Cleopatra[b]	245.325 x 500	20	0.001
Sweet orange	169.777 x 500	24	0.001
Hybrids[a]			
Own root[c]	45.935 x 100	20	0.001

[a]Not included in X^2 test.

[b]"Seedling" not included in X^2 test.

[c]"Navel" not included in X^2 test.

TABLE 26.--Summary of chi-square test of age groups by locations of varieties

Variable	Chi-square	d.f.	Probability
Age group by location of:			
Hamlin	116.151 x 2000	16	0.001
Early seedy	124.209 x 2000	16	0.001
Navel	47.166 x 2000	16	0.001
Jaffa	18.351 x 1000	16	0.001
Mid-season seedy	263.456 x 2000	16	0.001
Seedling	66.801 x 1000	16	0.001

TABLE 27.--Summary of chi-square test of age group by diseases of varieties

Variable	Chi-square	d.f.	Probability
Age group by disease of:			
Hamlin[a]	171.667 x 100	28	0.001
Early seedy[a]	146.643 x 100	28	0.001
Navel[a]	46.269 x 50	28	0.001
Jaffa[a]	134.472 x 50	28	0.001
Mid-season seedy[a]	485.496 x 100	28	0.001
Seedling[b]	373.496 x 10	28	0.001
Valencia	635.109 x 100	32	0.001

[a]Lightning injury not included in X^2 test.

[b]Xyloporosis not included in X^2 test.

TABLE 28.--Summary of chi-square tests of locations by diseases of age groups

Variable	Chi-square	d.f.	Probability
Location by disease of:			
Less than 4 years	288.911 x 10	32	0.001
5-9 years	481.088 x 100	32	0.001
10-14 years	332.570 x 100	32	0.001
15-24 years	1410.884 x 100	32	0.001
25 years and over	142.415 x 1000	32	0.001

TABLE 29.--Summary of chi-square tests of locations by rootstocks of age groups

Variable	Chi-square	d.f.	Probability
Location by rootstock of:			
Less than 4 years[a]	1115.780 x 1000	16	0.001
5-9 years[a]	209.900 x 5000	16	0.001
10-14 years[a]	647.872 x 1000	16	0.001
15-24 years[a]	345.093 x 5000	16	0.001
25 years and over[a]	836.438 x 5000	16	0.001

[a]Trifoliate and Hybrids not included in X^2 test.

TABLE 30.--Summary of chi-square tests of diseases by rootstocks in locations

Variable	Chi-square	d.f.	Probability
Disease by rootstock in:			
North Fringe[a]	547.076 x 10	28	0.001
West Coast[a]	146.598 x 100	28	0.001
Upper Interior[a]	648.490 x 100	28	0.001
Lower Interior[a]	1137.718 x 100	28	0.001
East Coast[a]	697.685 x 100	28	0.001

[a]Trifoliate and Hybrids not included in X^2 test.

TABLE 31.--Summary of chi-square tests of diseases by varieties in locations

Variable	Chi-square	d.f.	Probability
Disease by variety in:			
North Fringe[a]	135.787 x 100	42	0.001
West Coast	201.365 x 100	48	0.001
Upper Interior	619.773 x 100	48	0.001
Lower Interior[a]	374.110 x 100	42	0.001
East Coast[b]	62.710 x 100	30	0.001

[a]Lightning injury not included in X^2 test.

[b]Spreading decline, xyloporosis and lightning injury not included in X^2 test.

TABLE 32.--Summary of chi-square tests of rootstocks by age groups with diseases

Variable	Chi-square	d.f.	Probability
Rootstock by age group with:			
Psorosis[a]	102.150 x 50	16	0.001
Tristeza[b]	133.576 x 10	12	0.001
Spreading decline[c]	27.164 x 100	8	0.001
Water damage[a]	173.464 x 100	16	0.001
Blight [a,d]	3.680 x 100	12	0.001
Xyloporosis[a]	917.027	16	0.001
Foot rot[a]	146.437 x 100	16	0.001
Heart rot[b]	98.208 x 100	12	0.001
Lightning injury[b]	131.180	12	0.001

[a]Trifoliate and Hybrids not included in X^2 test.

[b]Trifoliate, water damage and Hybrids not included in X^2 test.

[c]Only rootstock data tested were sour orange, rough lemon and own root.

[d]Tree age less than 4 years not included in X^2 test.

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BIOGRAPHICAL SKETCH

Chen-Tuan Li was born in Kiangsu Province, China, on February 15, 1921. He received the Degree of Bachelor of Science in Land Economics from the National Chengchi University in 1947.

Following graduation from that institution, he passed the Civil Service examination and was given a position in the Ministry of Land Administration. Two years later he was transferred to the Ministry of Interior where he served in the capacity of a land specialist. Prior to coming to the United States for graduate study in September 1957, he was head of a section in the Department of Land Administration of the Ministry of Interior of Nationalist China.

He received the Master of Science in Agriculture degree from the University of Florida in 1959. In the same year he began advanced study for his doctoral degree. He was the holder of a graduate assistantship at the University of Florida for three and a half years and of a research assistantship for one year. He is a candidate for the degree of Doctor of Philosophy, major in Agricultural Economics, in August 1962.

He is a member of Gamma Sigma Delta.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 11, 1962

M. A. Brooker
Dean, College of Agriculture

Dean, Graduate School

Supervisory Committee:

Cecil N. Smith
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